Faculty of Manufacturing Engineering

INTEGRATION MODEL OF LEAN AND CLEANER PRODUCTION FOR SUSTAINABLE AND RESPONSIVE MANUFACTURING IN MALAYSIA

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DECLARATION

I declare that this thesis entitled "Integration Model of Lean and Cleaner Production for Sustainable and Responsive Manufacturing in Malaysia" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

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DEDICATION

In the name of Allah, the Most Gracious, the Most Merciful and all praises to the Prophet, Muhammad S.A.W. Alhamdulillah, praise to Allah for His mercy, I have successfully completed this project in a timely manner.

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ABSTRACT

Sustainability and responsive manufacturing were two performance criteria's that need to be balanced to remain competitive in a challenging manufacturing environment. In achieving this equilibrium, the integration of lean and cleaner production perceived to offer a robust tactical action to meet the sustainable and responsiveness performance. Thus, the objective of this research is to develop an integration model of lean and cleaner production for a better performance on sustainability and responsiveness by Malaysian manufacturing firms. In this research, the survey data from 107 manufacturing firms in Malaysia is used. A preliminary analysis shows that the implementation of lean production in environmental management has a significant relationship to the implementation of cleaner production in layout design, logistics design, and in assessing the impacts of manufacturing systems on the economic and environmental sustainability. This was achieved through an ongoing support and commitment by management. Meanwhile, through an advanced statistical analysis using Partial Least Squared-Structural Equation Modelling (PLS-SEM), the validated structural models are developed. The results from PLS-SEM analysis show that lean and cleaner production practices have a direct positive effect on economic and competency sustainability with a path coefficient value (β) above 0.3 at the significant p-value<0.01, while only cleaner production practices has a significant effect on environmental sustainability (β=0.704, p-value<0.01). Analysis also shows that both lean and cleaner production practices have produced a significant positive effect on the performance of manufacturing responsiveness at β-value above 0.3, $p<0.01$. In the meantime, the presence of the manufacturing responsiveness as a mediator has produced a significant indirect effect on environmental and economic sustainability ($\beta>0.4$, $p<0.01$), although the direct effect of cleaner production on economic sustainability has been compromised. Despite that, the presence of manufacturing responsiveness is apparent to break the effect on competency sustainability, although the direct effect is positive and significant. This validated integration model has a significant implication in translating the strategy and policies into action, especially to absorb any changes or uncertainty in economic and environmental sustainability issues. In addition, researchers, industrial practitioners, government and local authority can refer this integration model to understand the diverse effects of the integration of lean production and cleaner production, as well as to identify the strength and weaknesses in setting the strategy and policies to achieve the basis of implementation for sustainable and responsiveness manufacturing.

ABSTRAK

Kelestarian dan responsif pembuatan adalah dua kriteria prestasi yang perlu diimbangi untuk kekal kompetitif dalam persekitaran pembuatan yang mencabar. Bagi mencapai keseimbangan ini, integrasi amalan pengeluaran kejat dan pengeluaran bersih dilihat dapat membentuk keteguhan tindakan taktikal yang diperlukan bagi mencapai kedua-dua tahap prestasi kelestarian dan responsif. Justeru, objektif penyelidikan ini adalah untuk membentuk satu model integrasi antara pengeluaran kejat dan pengeluaran bersih bagi mencapai prestasi kelestarian dan responsif pembuatan yang lebih baik oleh firma pembuatan di Malaysia. Dalam kajian ini, data kajian soal selidik daripada 107 firma pembuatan di Malaysia digunakan. Analisis awalan menunjukkan pelaksanaan pengeluaran kejat dalam pengurusan alam sekitar mempunyai hubungan yang signifikan terhadap pelaksanaan pengeluaran bersih dalam rekabentuk susunatur, logistik, dan dalam menilai kesan sistem pembuatan terhadap kelestarian ekonomi dan alam sekitar. Ini dicapai melalui sokongan dan komitmen yang berterusan oleh pihak pengurusan. Sementara itu, melalui analisis statistik lanjutan menggunakan Partial Least Squared-Structural Equation Modelling (PLS-SEM), model struktur yang disahkan secara statistik dibangunkan. Keputusan daripada analisis PLS-SEM menunjukkan amalan pengeluaran kejat mempunyai kesan langsung yang positif terhadap kelestarian ekonomi dan kompetensi dengan nilai pekali laluan (β) melebihi 0.3 dan signifikan pada nilai-$p<0.01$, manakala amalan pengeluaran bersih hanya mempunyai kesan yang signifikan ke atas kelestarian alam sekitar ($\beta=0.704$, nilai-$p<0.01$). Analisis juga menunjukkan kedua-dua amalan pengeluaran kejat dan pengeluaran bersih telah menghasilkan kesan positif yang signifikan ke atas prestasi pembuatan responsif pada nilai-β melebihi 0.3, dan $p<0.01$. Disamping itu, kehadiran pembuatan responsif sebagai pengantara telah menghasilkan kesan tidak langsung yang signifikan terhadap kelestarian alam sekitar dan ekonomi ($\beta>0.4$, $p<0.01$), walaupun kesan langsung pengeluaran bersih terhadap kelestarian ekonomi telah terjejas. Namun begitu, kehadiran pembolehubah pembuatan responsif telah memutuskan kesan tidak langsung ke atas kelestarian kompetensi, walaupun menghasilkan kesan langsung yang positif dan signifikan. Model integrasi ini memberi implikasi yang signifikan dalam menterjemah strategi dan dasar kepada tindakan, terutamanya bagi menyerap sebarang perubahan atau ketidakpastian dalam isu-isu kelestarian ekonomi dan alam sekitar. Selain itu, penyelidik, pengamal industri, kerajaan dan pihak berkuasa tempatan boleh merujuk model integrasi ini untuk memahami kepelbagaian kesan integrasi pengeluaran kejat dan pengeluaran bersih, dan seterusnya mengenalpasti kekuatan dan kelemahan dalam menetapkan strategi dan dasar untuk mencapai asas perlaksanaan pembuatan lestari dan responsif.

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AOC	-	Asian Ownership Company
APG	-	Automotive Product Groups
AVE	-	Average Variance Extracted
CEC	-	Cleaner Environmental Compliance
CFA	-	Confirmatory Factor Analysis
CI	-	Continuous Improvement
CMA	-	Cleaner Management Awareness
CMO	-	Cleaner Material Optimization
CoE	-	Centre of Excellence
CP	-	Cleaner Production
CPG	-	Chemical Product Groups
CPP	-	Cleaner Production Practices
CR	-	Composite Reliability
CT	-	Cleaner Technology
CTES	-	Cleaner Technology Extension Services
CTIS	-	Cleaner Technology Information Service
CTO	-	Cleaner Technological Optimization
DANCED	-	Danish Cooperation for Environment and Development
DMSC	-	Do Not Have Any Management Certification
DOE	-	Department of Environmental
DOSM	-	Department of Statistics Malaysia
ECP	-	Environmental Conservation Programmes
EEPG	-	Electric and Electronics Product Groups
EM	-	Environmental Management
MMR	-	Manufacturing Market Responsiveness
EOP	-	End of Pipe
EQA	-	Environmental Quality Act

ERA	-	Environmental Recycling Activity
FMM	-	Federation of Malaysian Manufacturers
GDP	-	Gross Domestic Product
GIVC	-	Green Industry Virtual Centre
HRM	-	Human Resource Management
HTMT	-	Heterotrait-Monotrait Ratio of Correlations
ICC	-	Innovative and Creative Circle
ILO	-	International Labour Organization
IMR	-	Information Responsiveness
IMVP	-	International Motor Vehicle Programme
INPD	-	Involve in New Product Development
IOMC	-	ISO14001 Management Certification and Other Certification
IPI	-	Industrial Production Index
ISO	-	International Organization of Standardization
JIT	-	Just in Time
KeTTHA	-	Kementerian Tenaga, Teknologi Hijau dan Alam Sekitar
KMO	-	Kaiser-Meyer-Olkin
K-S	-	Kolmogorov-Smirnov
LCA	-	Life Cycle Assessment
LCP	-	Lean Cleaner Production
LM	-	Lean Manufacturing
LP	-	Lean Production
LPO	-	Lean Process Optimization
LPP	-	Lean Production Practices
LV	-	Latent Variables
LWO	-	Lean Work Organization
M	-	Mediator Variable
MIDA	-	Malaysia Investment Development Authority
MITI	-	Ministry of International Trade and Industry
MOC	-	Malaysian Ownership Company
MOF	-	Ministry of Finance
MOSTI	-	Ministry of Science, Technology and Innovation
MPC	-	Malaysia Productivity Corporation
MPG	-	Mechanical Product Groups

MR	-	Manufacturing Responsiveness
MRS	-	Manufacturing Responsiveness Performance
MS	-	Manufacturing Sustainability
MSP	-	Manufacturing Sustainability Performance
MSPc	-	Society Competency Sustainability Performance
MSPe	-	Environmental Sustainability Performance
MSPf	-	Economic Sustainability Performance
NINPD	-	Not Involve in New Product Development
NPC	-	National Productivity Corporation
OECD	-	Organization of Economic Co-operation and Development
OMC	-	Other's Management Certification
OPG	-	Other Product Groups
OTED	-	One Touch Machine Setup
PLS	-	Partial Least Square
RM	-	Ringgit Malaysia
SEM	-	Structural Equation Modeling
SIRIM	-	Standards and Industrial Research Institute of Malaysia
SM	-	Supplier Chain Practices
SME-Corp	-	SME Corporation Malaysia
SMED	-	Single Minutes Exchange Die
SMEs	-	Small and Medium Enterprise
SPSS	-	Statistical Packages for Social Science
TPM	-	Total Productive Maintenance
TPS	-	Toyota Production System
TQM	-	Total Quality Management
UEOC	-	US and Europe Ownership Company
UN	-	United Nations
UNEP	-	United Nations Environmental Programme
UNIDO	-	United Nations Industrial Development Organization
US	-	United States
VIF	-	Variance Inflation Factor
WIP	-	Work In Progress
X	-	Causal Variable
Y	-	Outcome Variable

LIST OF SYMBOL

β	-	Path Coefficient
CO_2	-	Carbon Dioxide
f^2	-	Effect size for Coefficient of Determination
NO_x	-	Nitrogen Monoxide
q^2	-	Effect size for Predictive Relevance
Q^2	-	Predictive Relevance
R^2	-	Coefficient of Determination
SO_2	-	Sulphur Dioxide